PRODUCTION OF FUEL BRIQUETTES FROM HYBRID WASTE (BLEND OF SAW-DUST AND GROUNDNUT SHELL)

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ABSTRACT

There is a great increase in the demand and cost of energy globally. The cost of purchasing petrol fuel is quite high; this has led the rural dwellers to concentrate on firewood as an alternative means of cooking, action which has greatly affected our ecosystem. This research is focused on the production of briquettes using waste sawdust and groundnut shell with starch and condemn oil as binder. These waste materials can be converted into a product that will provide alternative energy to the people rather than constituting environmental problems. The briquettes were produced using a modified briquetting machine developed at the Federal University of Petroleum Resources Engineering workshop. It was observed that the density of the briquette produced increased with blend ratio, amount of binder and compaction time. Optimisation technique predicted briquette density of 278.1 kg/m^3 *at the optimal level of 8.0, 10% and 50 minutes for the blend, binder and compaction time respectively. Combustion related properties of the briquette at the optimum level were density(277.9 kg/m*^{3}*), ash content (25.29%), moisture content (4.68 %wt), bulk density (3.03) g/cm*^{3}*) and burning rate (0.46 g/min) and these values are in accordance with previous research studies. Conclusively, the briquette fuel formed is effective, affordable and can be used as solid fuels to support heating in local and industrialized settings. In addition, establishing a small briquetting firm will serve as an alternative source of energy for cooking, create job opportunities and raise the standard of living of youths.*

KEYWORDS: *Briquette, density, ash content, moisture content, bulk density, burning rate*

1.0 INTRODUCTION

The production of fossil fuel globally will start depreciating in 20 to 30 years' time. This has been the major concern of scientist and engineers worldwide (Adegoke and Kuti, 2005; Adegoke and Mohammed, 2002). In emerging countries, organic waste offers approximately 20 to 33% of aggregate energy demand (Vargas-Moreno et al., 2012). Biomass, a general name for all dry plant materials and organic waste is well appreciated in Nigeria. This is because it is easy to access and can be obtained at no cost.

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They are commonly used in rural communities. Most rural dwellers cannot afford the price of prevalent fuels such as kerosene and cooking gas necessary to meet their daily domestic needs. Electric bill is on the high side in Nigeria and the populace often experience constant epileptic power supply thus making life very difficult especially for those who use electric stoves. Hence, the need for firewood as an alternative source of fuel. The use of firewood for cooking has negative effect on the populace as a result of the smoke produced during burning. (Raymer 2006; Rehfuess 2006). Research is ongoing on a daily basis in search of substitute for firewood as a source of cooking and heating in homes. This solution has been obtained from by-products of agricultural waste which are available in large quantities and very useful in rural and urban region; developing and developed countries (Yank et al., 2016). Researchers in energy fields are giving so much attention to this area of research. Also, investigation on the production of eco-friendly briquettes is seen in fuel and energy literature (Thao et al., 2011).

2.0 REVIEW OF LITERATURE ON BIO-BRIQUETTES

However, a lot has been reported on briquette production Though most researchers focus on briquettes development using single waste material. Some of the research conducted include: Briquette production from cotton stalk (Abakr et al. 2006); briquette production from Rice husk (Sisman and Gezer 2011); briquette production from sawdust (Arinola et al., 2013, Chinyere et al. 2014); briquette production from hyacinth plant (Davies and Abolude 2013, Supatata et al. 2013, Rezania et al., 2016, Rezania et al., 2017); briquette production from rice (brand et al., 2017); briquette production from Pterocarpus Indicus Leaves (Anggono et al. 2017). It is possible to formulate briquettes from hybrid waste. Briquettes developed from hybrid waste will offer a cheap, eco-friendly and readily available solid fuel for domestic and commercial purposes. For instance, Olorunisola (2007) conducted research on briquette production using waste paper and coconut husk. Rajkumar and Venkatachalam (2013) researched on briquette production by combining Cutton, soya beans and pigeon pea stalk. Lubwama and Yiga (2017) developed a system for production of briquettes by binding together groundnut shell and bagasse. Nwabue et al., (2017) researched on briquette production from plastic and other waste materials with proper carbonization. Lubwama and Yiga (2018) researched on briquette production from rice and coffee husk. Wu et al., (2018) looked at the development of briquettes from waste material by combining wood sawdust and cotton stalk.

Sawdust and groundnut shell are popular waste materials in Nigeria. Thus, the production of briquettes from these waste will go a long way to discourage deforestation, pollution and environmental degradation (Okello et al., 2013). Also, very few studies exist in the literature on the utilization of condemned oil as a binder. Most researchers in previously reviewed work used cassava and starch as binder during briquette production. In this study, hybrid waste materials (sawdust and groundnut shell) is considered with condemned oil is used as binder. These materials were considered because they are prevailing and readily available waste materials. For instance, condemned oil as a waste material is usually disposed in hotels and restaurants, saw dust as waste are very much available in wood industries and groundnut shells are found at market place and farm land.

2.1 Sawdust as a Briquette Material

According to Kuti 2009, of all available biomass materials, wood contribute to the prevalent possible source of biomass which is very relevant in briquetting technology. To effectively address waste disposal issues in the timber and wood industry, it is important to convert the waste materials or sawdust into useful briquettes for domestic cooking and heating and for commercial purposes. This would greatly address the problem of pollution and unemployment (Tembe et al., 2014). Sawdust materials or wood waste are quite easy to come by and tend to be very relevant in briquette production (Kuti, 2009). Sawdust generated in Nigeria is very high in volume and sawmills dispose these waste in a careless manner. In the past, sawdust generated as waste material in sawmill were gathered together in an open area or field and set on fire. This act is hazardous and environmentally unfriendly. Presently, the act of burning sawdust in open places is discouraged. Research has shown that these waste materials are useful form of renewable or alternative energy which can serve as solid briquettes for heating in homes and industries. Kiss and Alexa (2015) researched further on sawdust and briquetting and observed that sawdust contains natural lignin which is present in wood. This helps in bonding process and as such sawdust require very little or no binder during the formation of briquettes. Though in the process of briquetting, there is need for greater compression of the raw material (sawdust and water) to form solid useful briquettes. Kiss and Alexa (2015) further stated that there are two types of briquettes produced from sawdust: solid briquettes and hollow briquettes. Solid briquettes are briquettes bonded together using piston press while hollow briquettes are briquettes produced with hole at the center using screw press. Hollow briquettes burn better than solid briquettes because of the presence of space for efficient combustion. The waste sawdust can serve as a source of wealth to the nation. (Oyelaran et al., 2015). Briquetting of sawdust is a traditional way of regulating the amount of heat released during burning process in homes and industries (Adetogun, 2014).

Kiss and Alexa (2015) are still of the opinion that raw sawdust have low burning efficiency. Conversely, when the materials are bonded together to form briquettes, they become solid biofuel with high burning efficiency and higher calorific value than firewood. The combustion process of briquettes made from sawdust is highly efficient compared to the combustion process of firewood during heating. This is as a result of the low moisture content of briquettes made from sawdust (4%). The moisture content of firewood is quite high (65%) (Kiss and Alexa, 2015).

2.2 Groundnut as a Briquette Material

Nigeria rank top on the list of foremost producer of groundnut globally. Research has shown that the average annual production of groundnut is about 1,000,000 tons (Oyelaran et al., 2015). One of the residue present in harvested groundnut is groundnut shell disposed as a waste material after shelling. It is important to note that this waste can be converted into useful briquette for cooking traditionally and industrially. The waste material is considered perfect for briquetting because of the low moist and ash content present (10% or lower and 2-3%) (Ajobo, 2014). Therefore, groundnut shell briquettes can serve as a substitute to firewood for cooking in homes and industries. A blend of sawdust and groundnut shell for briquette production is expected to produce highly efficient and effective briquettes for domestic cooking in rural and urban setting. This is the ultimate goal of the research.

3.0 MATERIALS AND METHODS

3.1 Materials, Reagents and Equipment

Sawdust (SD), groundnut shell (GNS) and starch were obtained from Okuokoko sawmill, Agbarho market and Ugbmro market, Uvwie Local Government Area in Delta state Nigeria. 200ml granulated cylinder, 200ml Pyrex beaker, electronic weighing balance (Pesson, Sweden), crucible (Logat, Finland) and Bunsen burner were utilized for the development of briquette synthesized from SD and GNS blends.

3.2 Processing of briquette from blending ratio of Groundnut Shell and Sawdust

A modified briquetting machine developed in the University workshop and was employed to conduct preliminary production of fuel briquettes from grinding of raw materials in Figure 1, to production of briquettes in Figure 2.

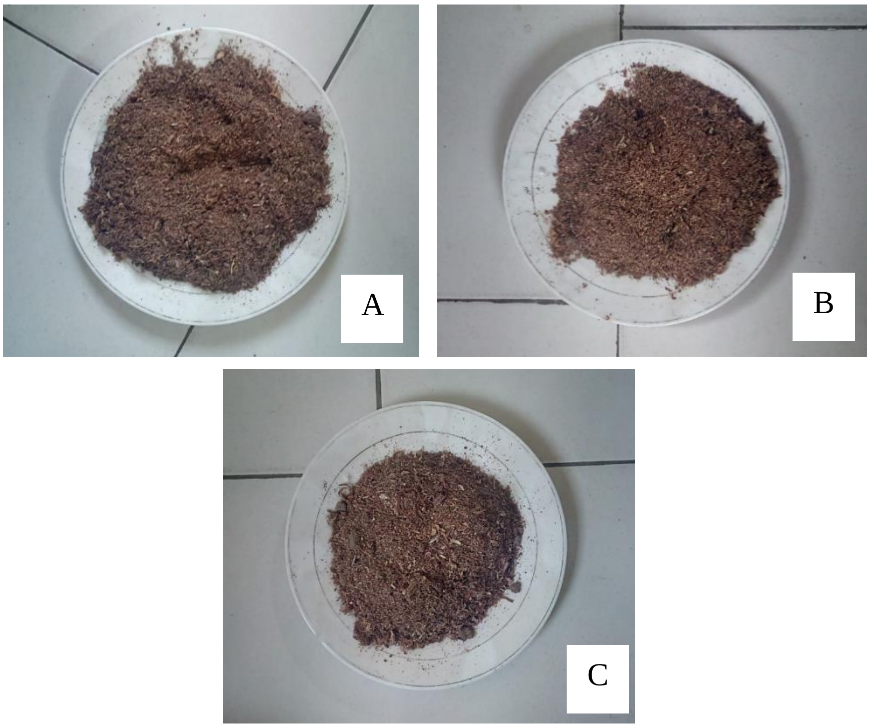


Figure 1. Prepared sample of sawdust : groundnut shell : starch ratio; A (90% groundnut shell : 8% sawdust : 2% starch); B (70% groundnut shell : 24% sawdust : 6% starch); C (50% groundnut shell : 40% sawdust : 10% starch)

The briquetting process entailed the grinding of the groundnut shell and smashing of sawdust. The smashing reduced the sizes of the feedstock into powdery form ranging from 3.5 to 5.5 meshes. The smashed feedstock was properly mixed with waste cooking oil and starch as binder prepared in the ratio 90:8:2, 70:24:6, 50:40:10 by mass percentage which are ratios of sawdust to groundnut shell and starch mixed with waste oil (sawdust: groundnut shell: starch with waste oil). Presented in Figure 2 is the prepared sample of the feedstock blending ratios. With adequate proportion of water added to the content, the briquetting operation continued as the mixture rolled into the mixing chamber, then to the barrel through the connector to the mould. The mould shaped the mixture into the desired briquette architecture and moved them directly below the hydraulic press to compress the briquettes while the heating element dry up the wet briquettes appropriately as they roll out of the chamber. Good quality briquettes were obtained thereafter, see Figure 2.

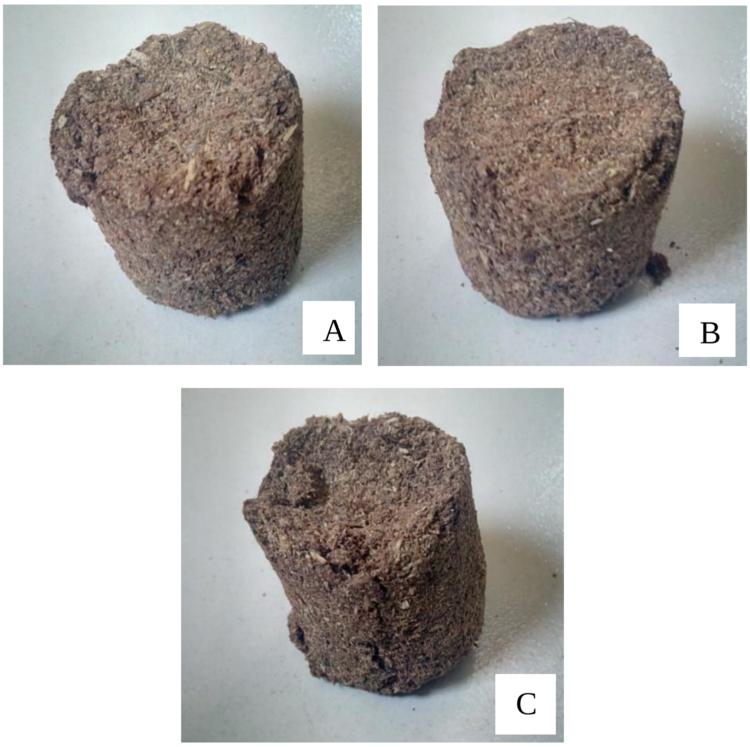


Figure 2. Solid briquettes from the blending ratios. A, B and C are 90:8:2, 70:24:6 and 50:40:10

4.0 STATISTICAL ANALYSIS OF BRIQUETTING PRODUCTION

The coded variables for the design of the experiment for briquette production from sawdust and groundnut shell with starch as additive are presented in the Table 1. Mixtures were prepared according to the parameters provided in Table 1 which was effectively computed using RSM software. The polynomial/quadratic equation of the response models is highlighted by Equations [1] and [2]. Where ρ is the density of the briquette produced (kg/m^3), A, B and C are the coded experimental input for saw dust: groundnut shell (A), starch amount (B) and compaction time (C), respectively. The quadratic model is obtained to estimate the density of the briquette including all experimental parameters. The variation of experimental density and predicted density is depicted by Figure 3 and Figure 4. The contours with response surfaces also generated by the model are shown in Figures 5 for all experimental variables.

Table 1. Design with briquetting machine and density from experiments as predicted by response surface methodology.

Actual A	Coded A	Actual B	Coded B	Actual C	Coded C	Experimental Density	Predicted Density	Residual
Saw dust or ground nut shell		Starch quantity		Compaction time				
		wt. %		Min		(kg/m^3)	(kg/m^3)	
8	-1	2	-1	10	-1	116.1	116.11	-0.007
40	1	2	1	10	-1	170.5	170.51	-0.007
8	-1	10	1	10	-1	155.7	155.71	-0.007
40	1	10	-1	10	1	179.6	179.61	-0.007
8	-1	2	-1	50	1	156.0	156.01	-0.007
40	1	2	1	50	1	112.9	112.91	-0.007
8	-1	10	1	50	1	278.1	278.11	-0.007
40	1	10	0	50	0	204.5	204.51	-0.007
8	-1	6	0	30	0	210.2	210.17	0.027
40	1	6	-1	30	0	200.6	200.57	0.027
24	0	2	1	30	0	93.6	93.57	0.027
24	0	10	0	30	-1	159.2	159.17	0.027
24	0	6	0	10	1	113.2	113.17	0.027
24	0	6	0	50	0	145.6	145.57	0.027
24	0	6	0	30	0	144.7	144.72	-0.018
24	0	6	0	30	0	144.7	144.72	-0.018
24	0	6	0	30	0	144.7	144.72	-0.018
24	0	6	0	30	0	144.7	144.72	-0.018
24	0	6	0	30	0	144.7	144.72	-0.018
24	0	6	0	30	0	144.7	144.72	-0.018

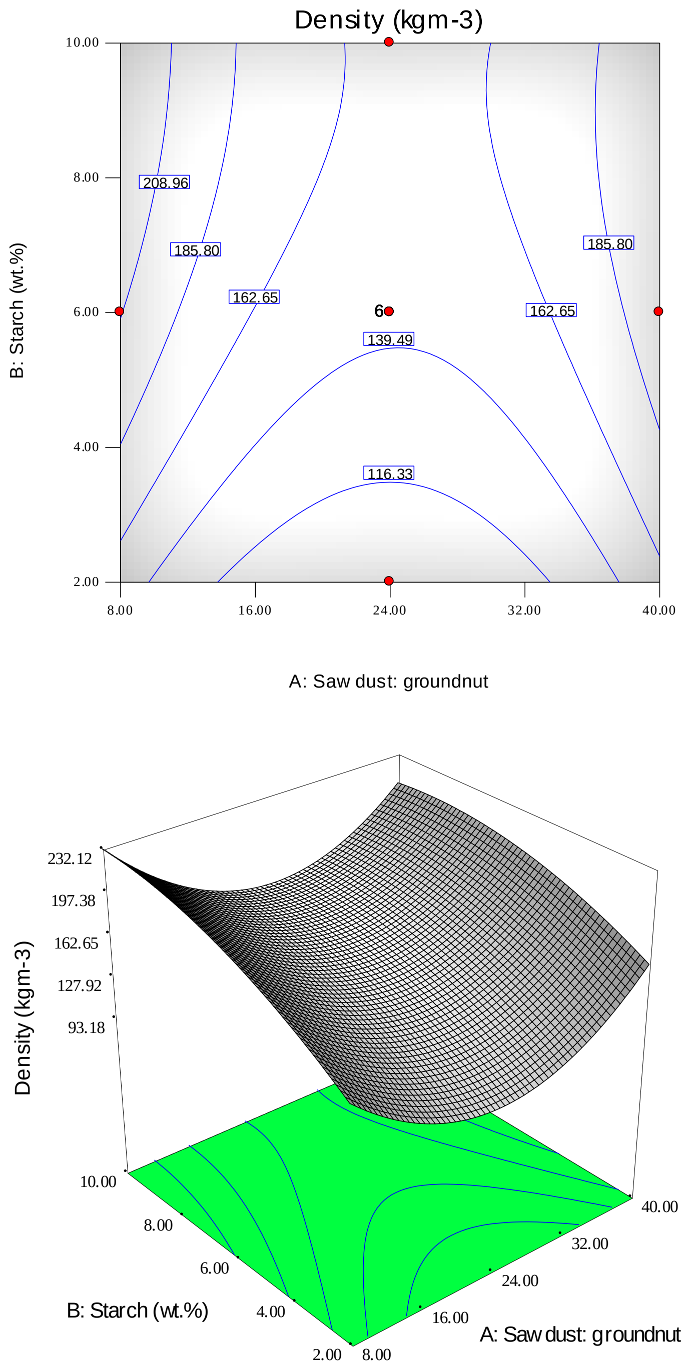
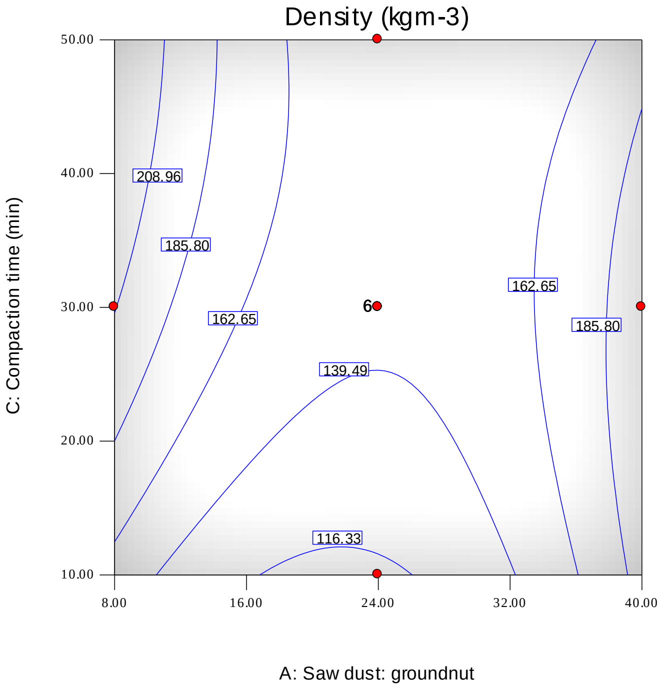


Figure 3. Contour plots and response surface for density of briquette as a function of sawdust-grounut shell and starch.



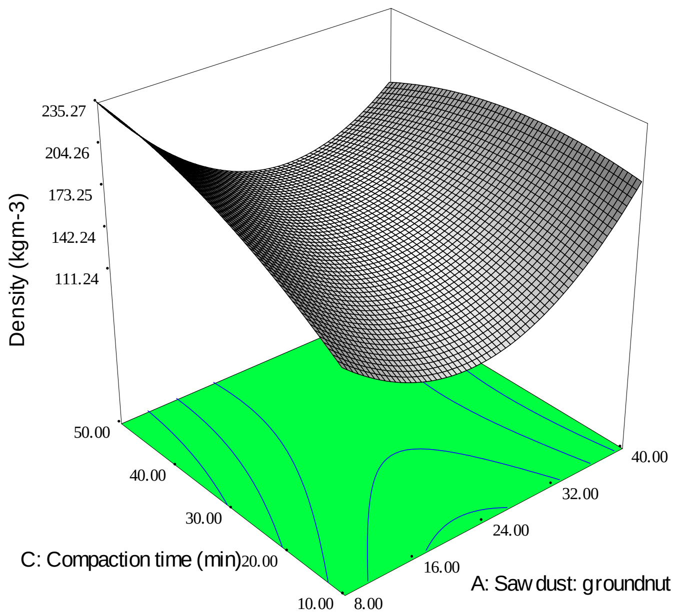
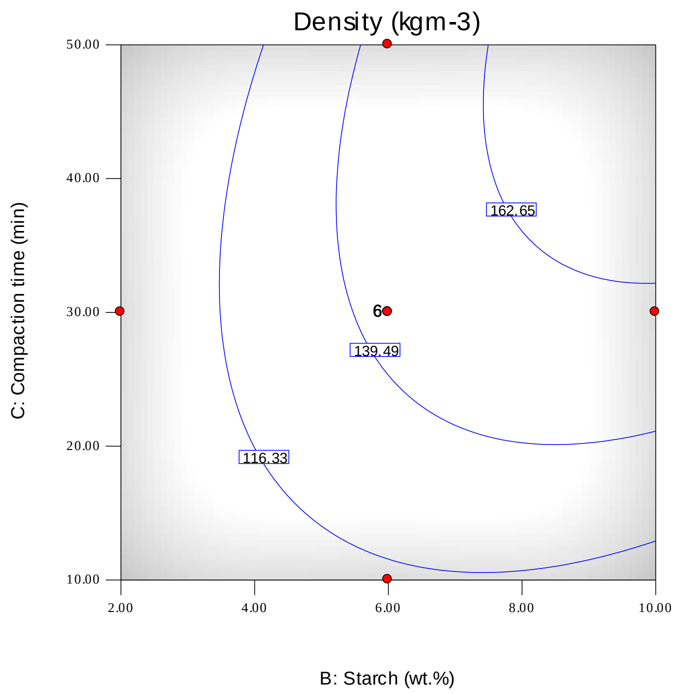


Figure 4. Contour plots and response surface for density of briquette as a function of sawdust-grounut shell and compaction time.



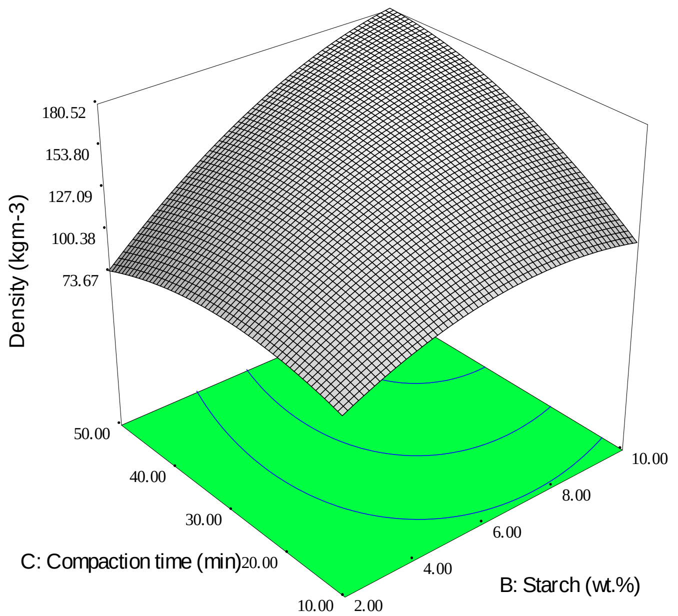


Figure 5. Contour plots and response surface for density of briquette as a function of compacttion time and starch.

4.1 Optimisation of Modified Quadratic Density Model

The predicted density obtained from the optimization technique of Design Expert 6.06 is shown in Table 2. The optimized values ranges from 93.6 to 278 kg/m^3 at various variable parameters. The predicted density is 4.87 kg/m^3. The estimated optimization values as a result of the experimental parameter is depicted in Table 3.

4.2 Characterisation of Briquette Produced

The Table 4 shows the characterised properties of a briquette sample. The briquette sample was produced as a result of the values obtained after optimization.

$$\rho = 144.75 - 4.8a + 32.8b + 16.2\, c^2 + 60.88\, a^2 - 18.12\, b^2 - 15.12\, c^2 - 7.63ab - 24.38\, ac + 20.63bc \tag{1}$$

$$\rho = 114.44 - 8.72A + 16.91B + 33.6\, C - 0.238\, A^2 - 1.13\, B^2 - 0.038C^2 - 0.12AB - 0.076\, AC + 0.26BC \tag{2}$$

Table 2. Optimization summary for modified yield response model

Solution Number	Saw dust: Ground nut shell (A)	Starch amount (w/w%) (B)	Compaction time (min) (C)	Estimated density of briquette (kg/m^3)	Desirability
			(% w/w)	(%)	
1	8.00	9.98	50.00	278.16*	1.00
2	8.74	10.00	50.00	270.96	0.961
3	8.00	10.00	43.93	267.41	0.942
4	8.00	7.26	49.47	252.27	0.860
5	8.00	10.00	32.31	238.98	0.788
6	40.00	9.53	38.66	209.28	0.483
7	40.00	6.25	17.71	200.51	0.442
8	40.00	6.57	15.77	199.75	0.439

*Optimal value selected

Table 3. Estimated optimization values of experimental parameters

Experiment	saw dust: ground nut shell	Starch amount (w/w%)	Compaction time (min)	Experimental density (kg/m^3)	Predicted density (kg/m^3)	% Error
1	8.00	10	50	5	4.87	0.2

Table 4. Characterised properties of the produced briquettes

Sample number	Density (g/cm^3)	Ash Content (%)	Moisture Content (%wb)	Bulk Density (g/cm^3)	Durability	Burning Rate (g/min)	Ignition Time (sec)
1	281.6	25.27	4.65	3.012	0.84	0.43	35.27
2	274.2	25.30	4.7	3.045	0.88	0.48	29.78
Mean	277.9	25.29	4.68	3.03	0.86	0.46	32.53
Standard deviation	0.01	0.02	0.03	0.02	0.02	0.03	2.75

5.0 DISCUSSIONS

5.1 Physical Properties of Sawdust-Groundnut Shell Blend

The physical properties of the feedstock taken from the individual blend ratio shows that moisture content increased with an increase in starch percentage from 4.18 to 11.62%. The ash content also increased with an increase in sawdust and groundnut shell ratio from 36.02 to 48.68%. Bulk density of the sawdust shifted from 3.77 to 3.85g/cm^3 as the starch percentage increased from 2 to 10%. The second degree order equations were found adequate to correlate the physical properties (moisture content, ash content and bulk density) with the starch content. The regression coefficient the high R^2 (1) implies that 100% of the physical characterisation was captured by the regression model equation.

5.2 Response Surface Methodology

The RSM results shows that the maximum density ranges from 93.6 to 278 kg/m^3. The input variables for briquette fuel for minimum density were 2% starch, sawdust/groundnut shell quantity of 24 and compaction time of 30 minutes while the maximum density of briquette was obtained at 10% starch, sawdust/groundnut shell quantity of 10% and a compaction time of 50 minutes. The contour plots and response surface graph shows sawdust-groundnut ratio varies within the range of 8 to 40 for density and starch fraction was varied from 2 to 10% with a briquetting density of 116.33 to 208.96 kg/m^3. In this present study, the optimum process was obtained at a ratio 24 for sawdust-groundnut shell at 6% of starch content, this was observed to be decreasing beyond 6% of starch and waste oil.

5.3 Optimization of Response Parameters

The numerical optimization of the modified density produced set of optimised solution for the maximization of density within experimental domain of sawdust-groundnut ratio (8), starch content (9.98wt%) and compaction time (50 minutes) with a predicted density of 278.16 kg/m^3 was chosen as the optimised parameter point of variables. The validation test using the optimised experimental variable yielded an experimental density of 5 kg/m^3. The average error between the predicted and experimental variable was found to be 2%. The model was accurate, since the percentage error was in good agreement.

6.0 CONCLUSIONS

At the end of this study, solid fuel briquette was produced from waste hybrid materials (SD and GNS) using the improved briquetting machine developed at Federal University of Petroleum Resources workshop in Delta State, Nigeria. The raw material is a blend of sawdust and groundnut shell with starch and waste oil as binder. The production of the desired briquette was actualized by effective determination of the physical properties of the feedstock. Response Surface Methodology (RSM) was used to find the range of values necessary to obtain quality briquettes from hybrid agro-waste. The briquettes produced from these values are of high quality with low moisture content and faster ignition time which symbolises a good briquette. Finally, this research can be expanded further via mass production. The briquette produced is: environmentally friendly; a good source employment opportunity; raise the standard of living of youths especially in rural area of Nigeria and the world at large. This will also reduce the expenditure on electricity as an alternative source of energy for cooking and warming the rooms in cold region.

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